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14. ABSTRACT
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Change in concentration with annealing suggests p-type Hg vacancies and n-type Se vacancies

OMSA suggests an inhomogeneous distribution of electrons introduced in growth, reduced with Hg then Se anneal

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Major source of HgCdSe background electron concentration is Group VII impurities (Br, Cl, F) introduced from Se source material

Change in concentration with annealing suggests p-type Hg vacancies and n-type Se vacancies

QMSA suggests an inhomogeneous distribution of electrons introduced in growth, reduced with Hg-then-Se anneal making mobility more discrete

Lower electron concentration allows us to see PCD transients, which suggest trap present in as-grown material that is increased with Hg-annealing but removed with Se-annealing, could be Se vacancies

Lowering background electron concentration and increasing lifetime will require higher purity Se and optimized anneal process

U.S. Army Research, Development & Engineering Command

Electron transport and Minority Carrier Lifetime in HgCdSe

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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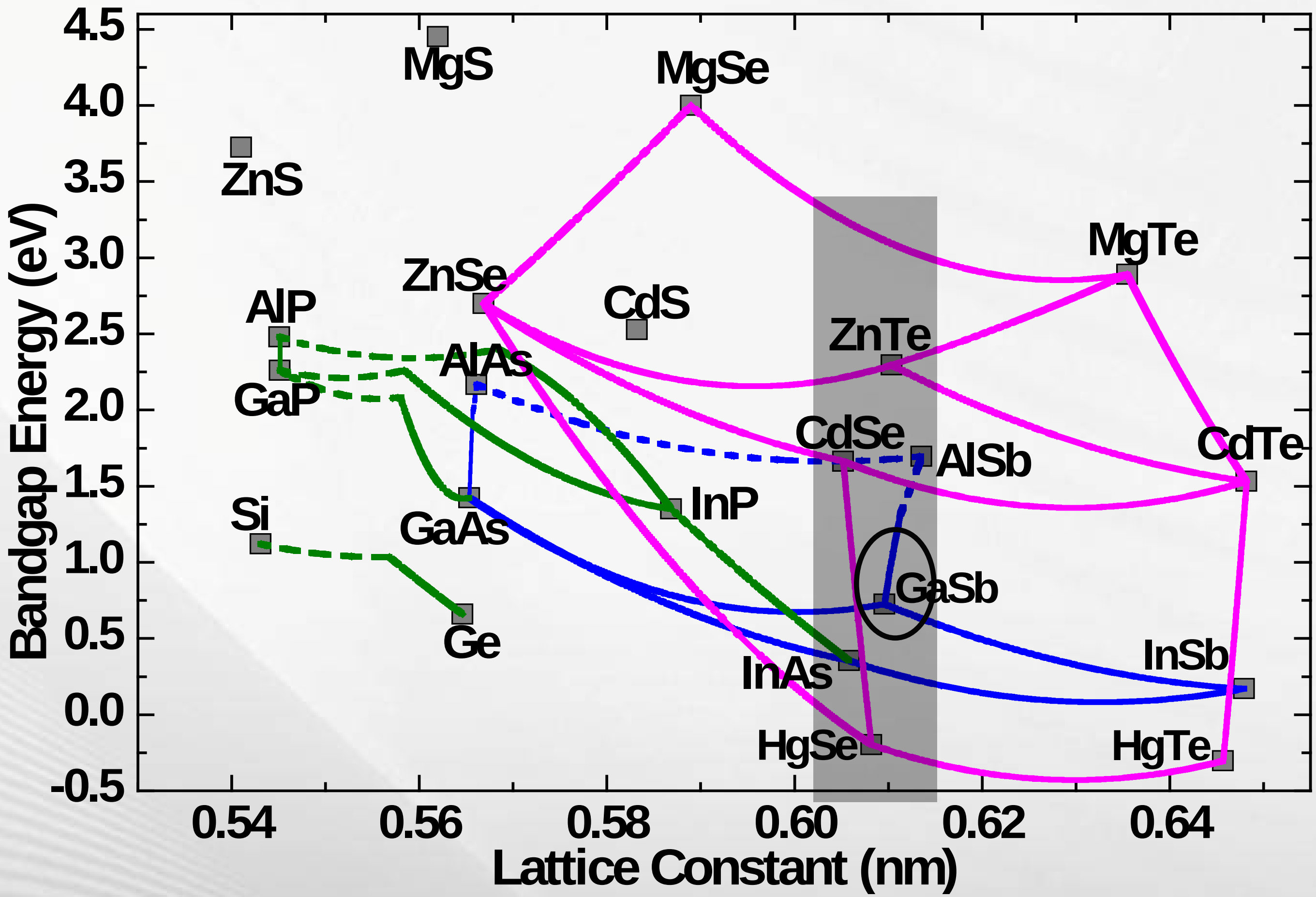
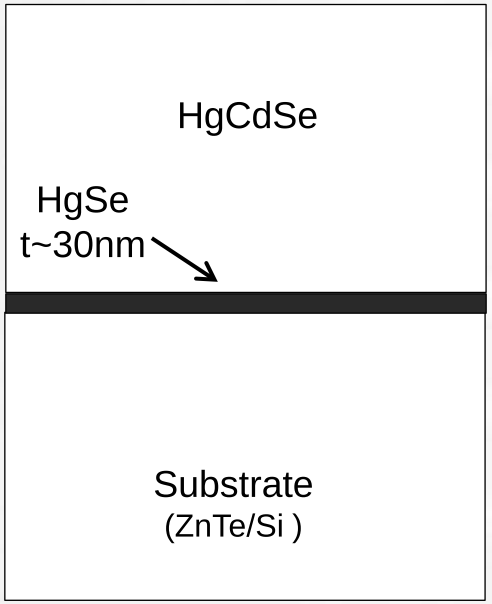
Alternative IR Material





Growth Structure

- HgCdSe is being investigated as an alternative IR material since it is closely lattice-matched to GaSb substrates.

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77K As-Grown Concentration

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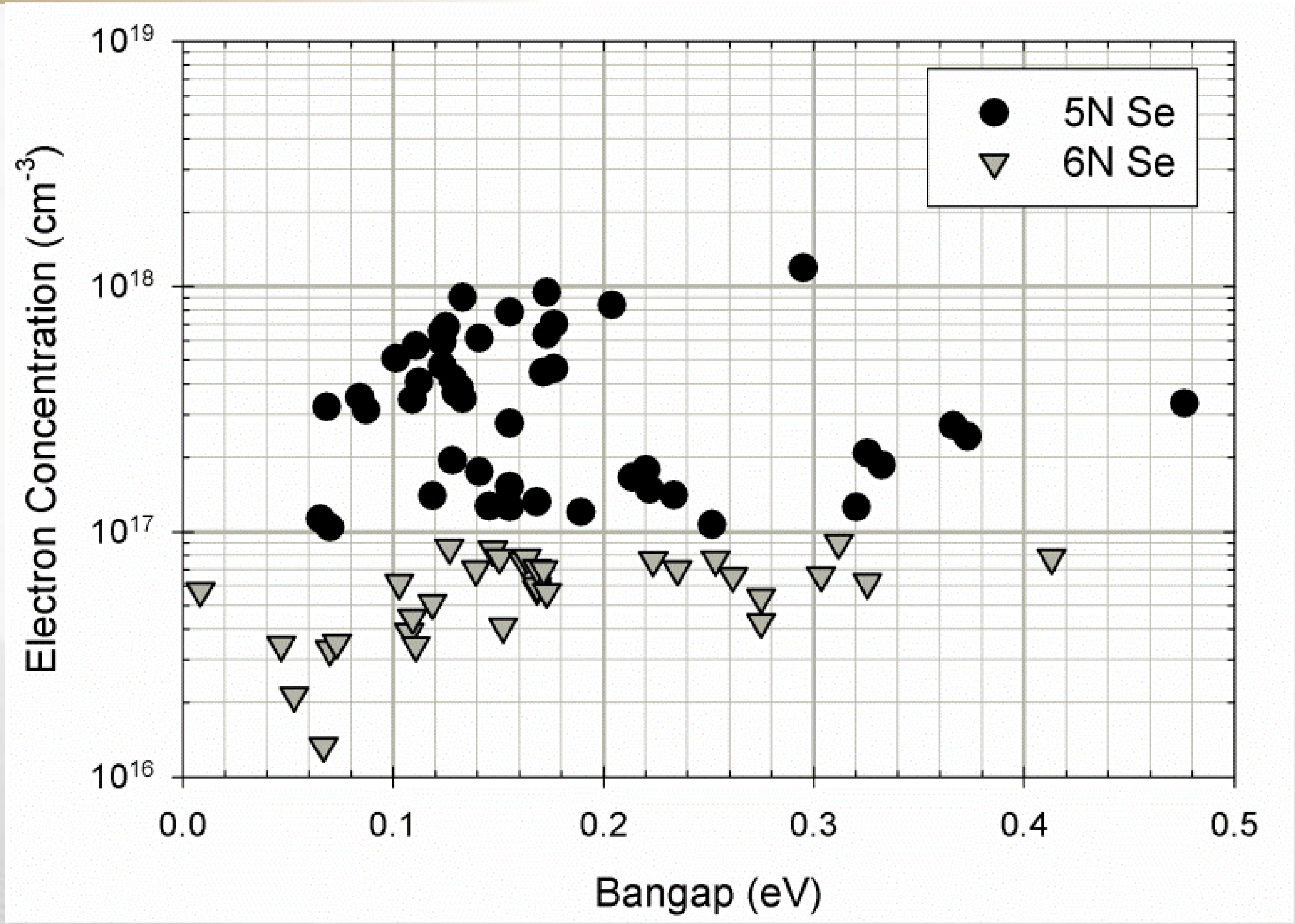
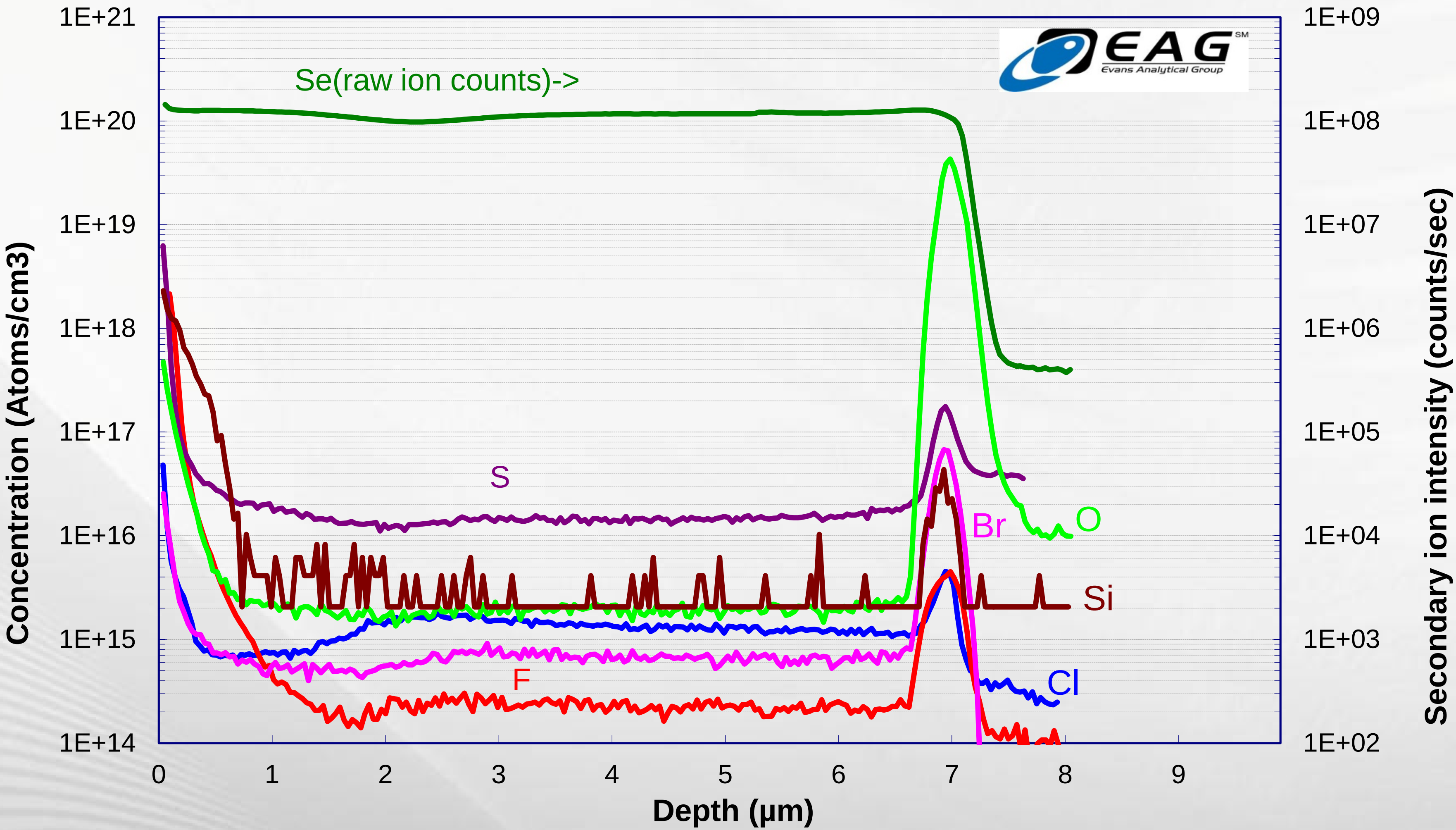


As-grown HgCdSe electron concentration reduced an order of magnitude by switching to higher purity Se source material

K. Doyle, *Doctoral Dissertation, WVU Library (2013).*

SIMS Measurements



Group VII impurities detected, particularly near the ZnTe interface. Could be acting as donors

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Group VII SIMS Concentrations

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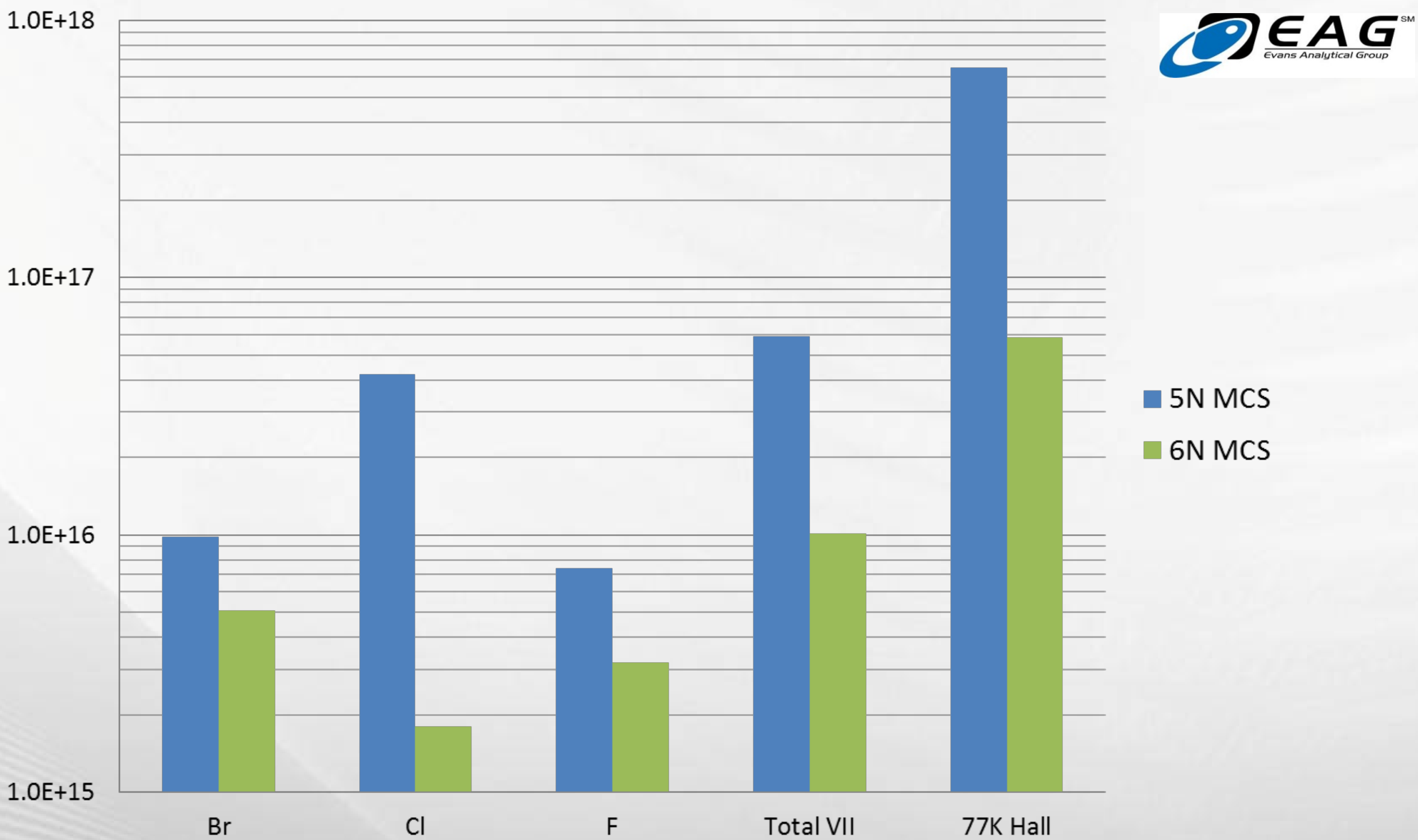
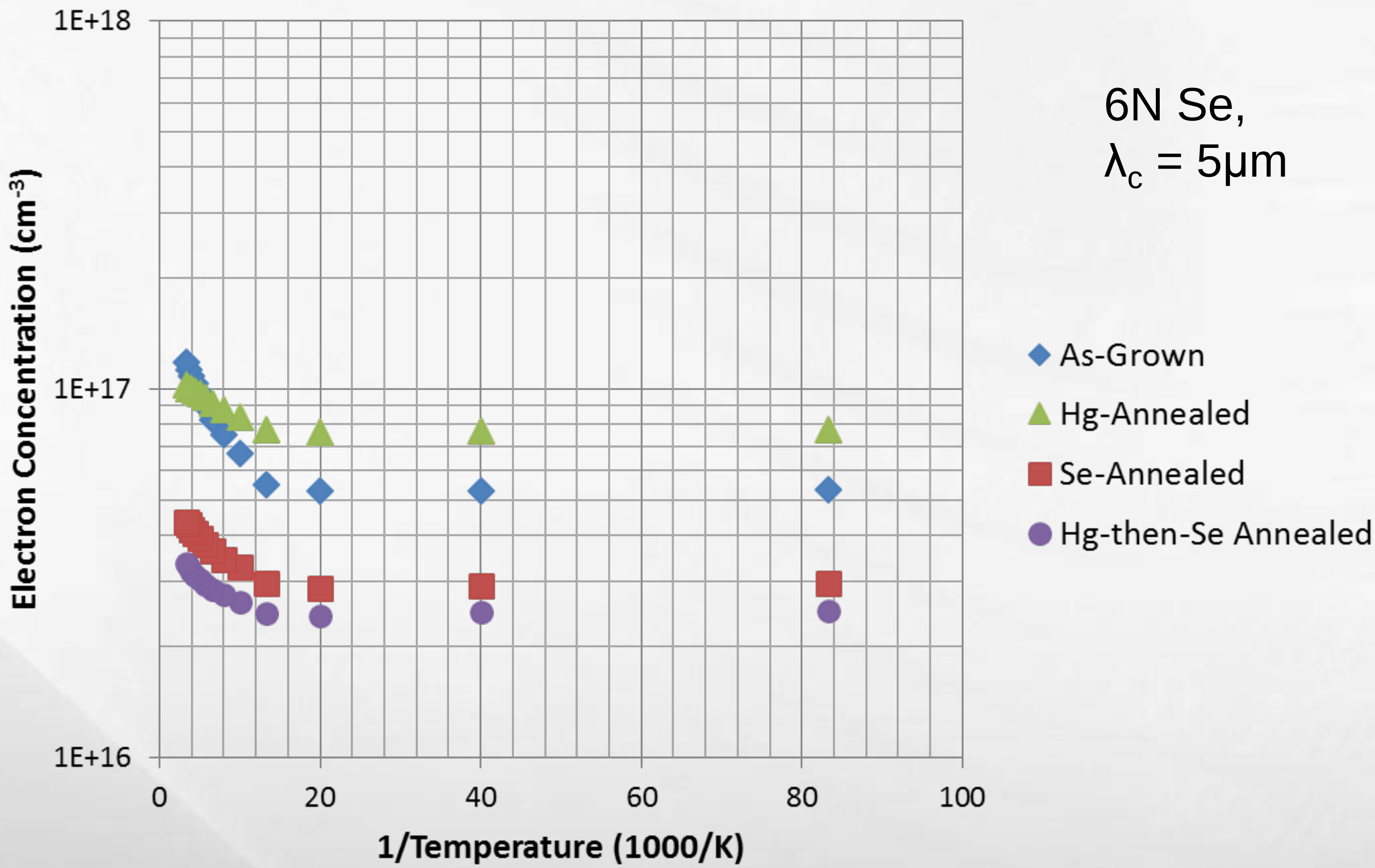


Reduction in electron concentration corresponds with reduction in Group VII elements detected by SIMS.

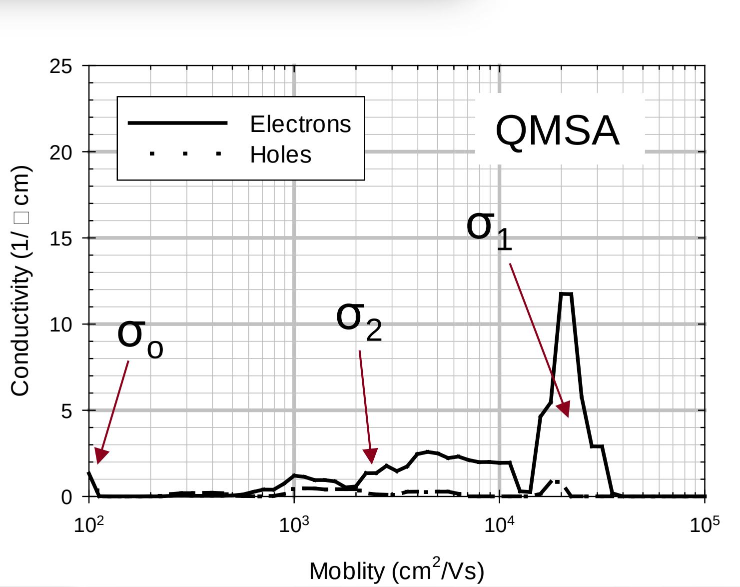
Electron Concentration vs. Temperature



6N Se,
λ_c = 5µm

- Electron concentration raised after Hg-annealing, lowered after Se annealing, suggests additional p-type Hg vacancies and n-type Se vacancies.
- Appear to have mixed conduction effects at higher temperatures

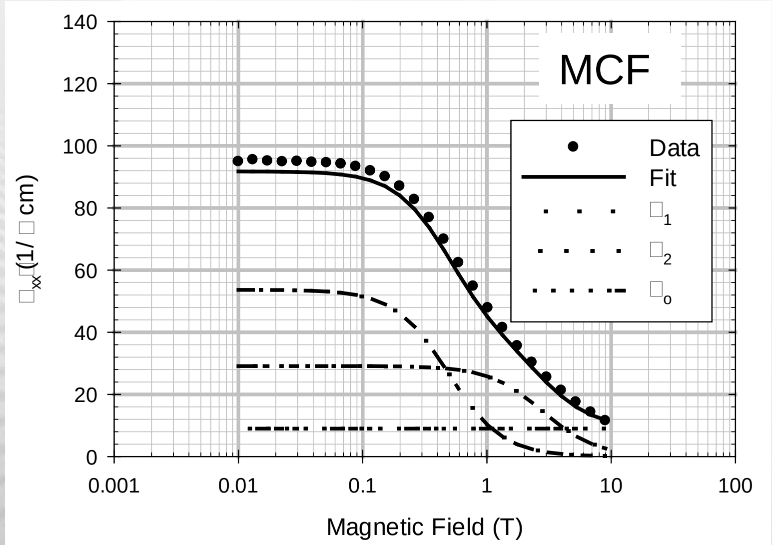
77K As-Grown Variable Field Hall

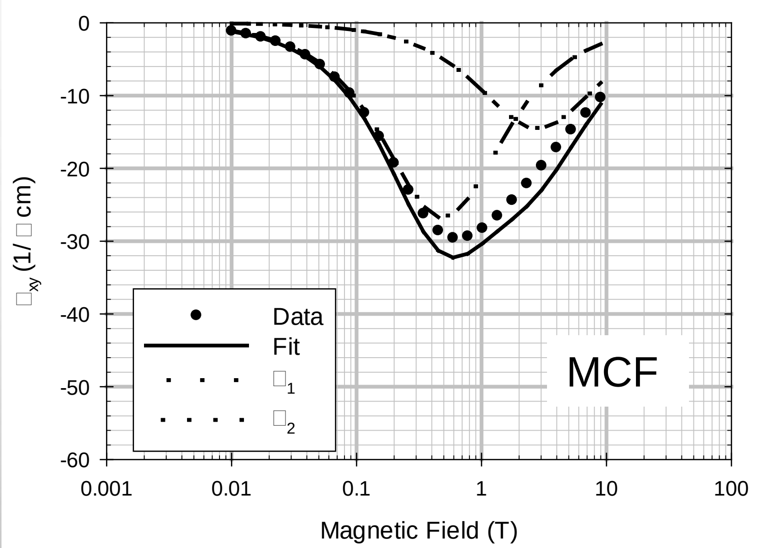


$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1+(\mu_1 B)^2} + \frac{en_2\mu_2}{1+(\mu_2 B)^2} + \sigma_o$$

(μB) <<1

$$\sigma_{xy}(B) = -\frac{en_1\mu_1^2 B}{1+(\mu_1 B)^2} - \frac{en_2\mu_2^2 B}{1+(\mu_2 B)^2}$$

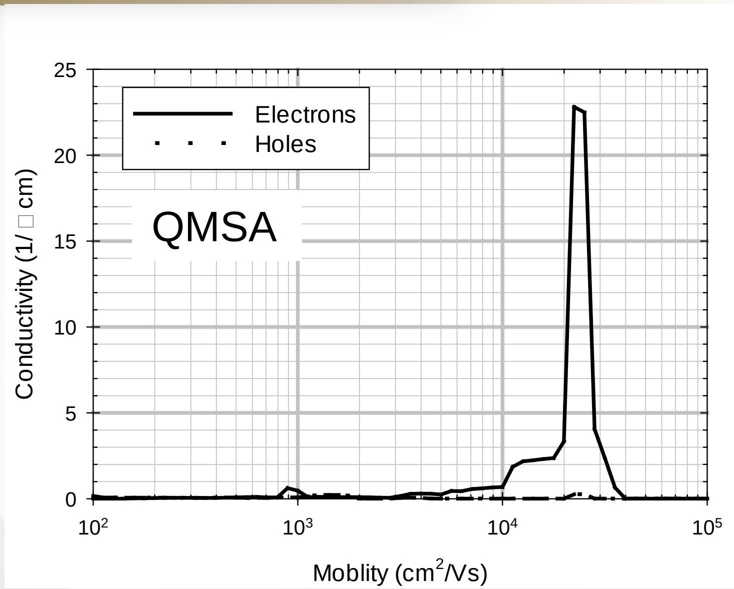




K. Doyle, *Doctoral Dissertation, WVU Library (2013).*

77K Annealed Variable Field Hall

Stage	Element	Temp.	Duration
1	Hg	250 °C	24 hrs
2	Se	250°C	24 hrs



$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1+(\mu_1 B)^2} + \frac{en_2\mu_2}{1+(\mu_2 B)^2} + \sigma_o$$

(μB) <<1

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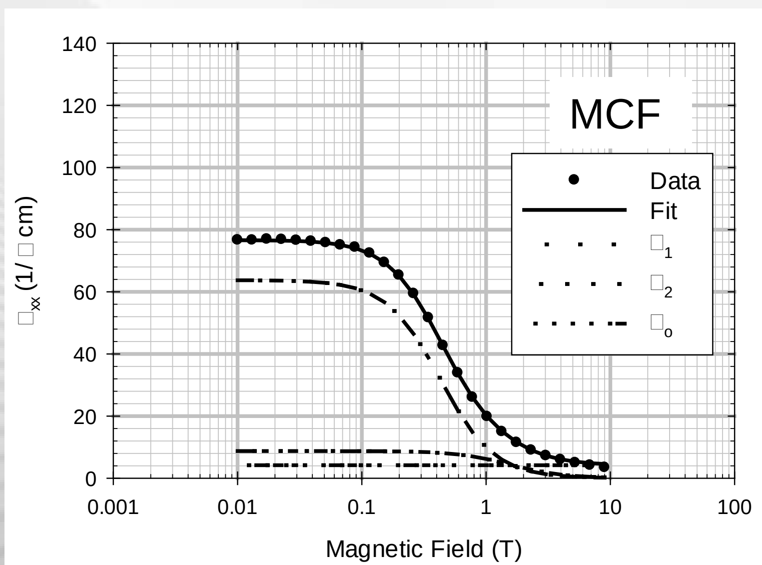

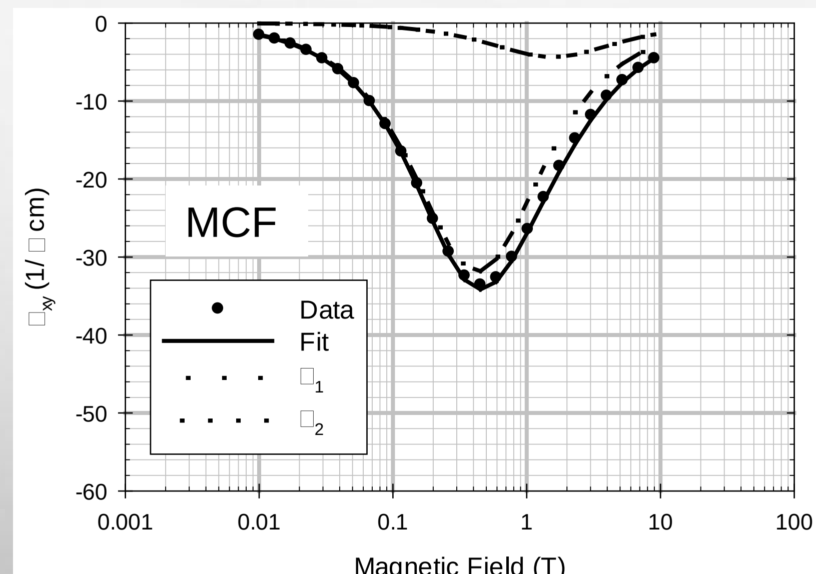

K. Doyle, *Doctoral Dissertation, WVU Library (2013).*

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Multi-Carrier Fit Results

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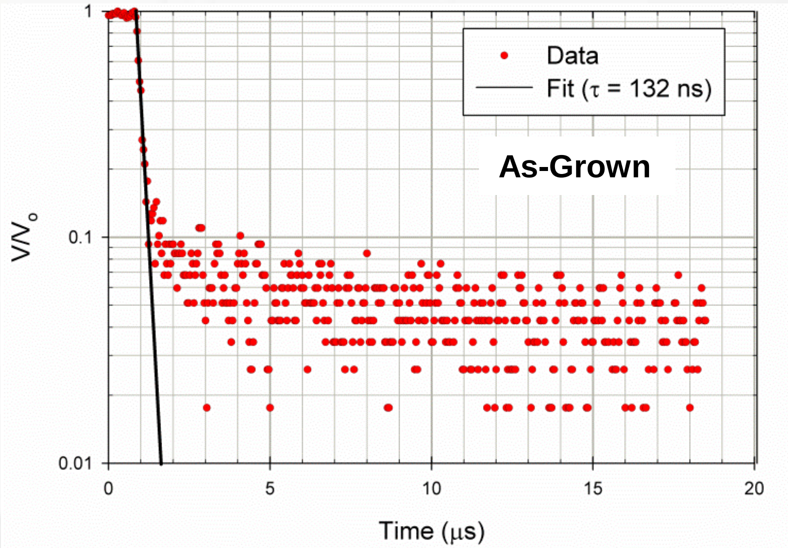
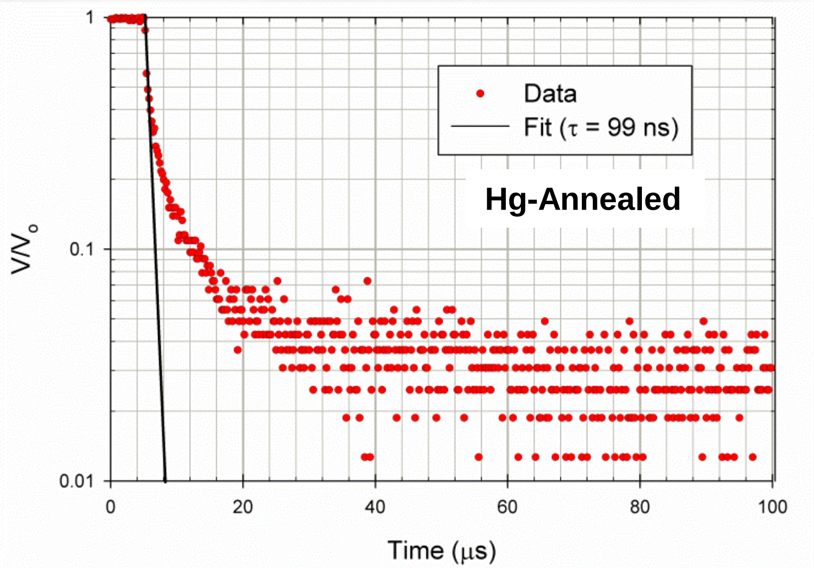
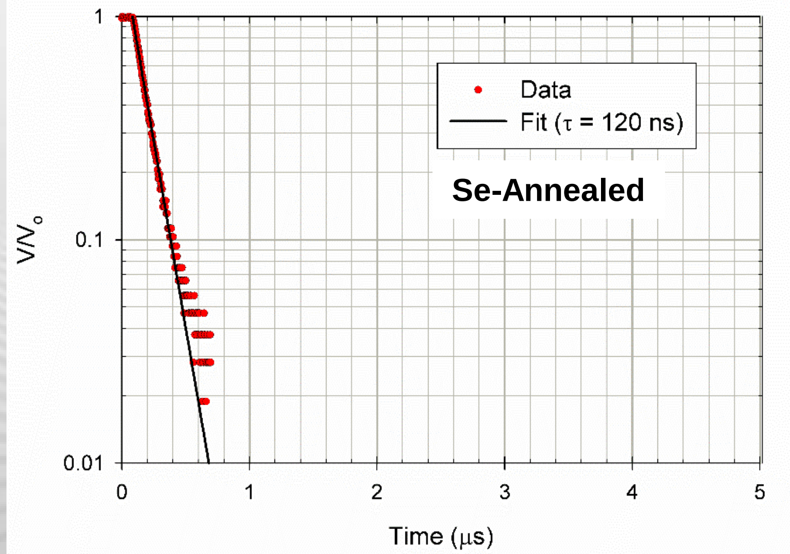
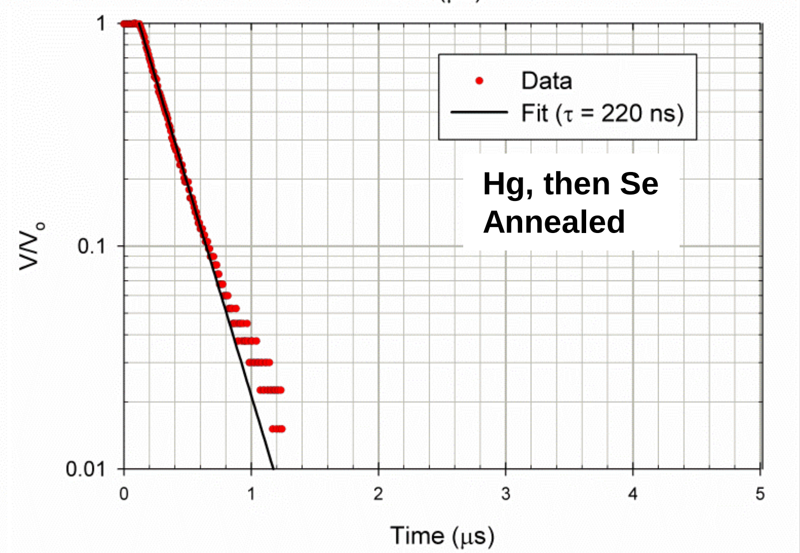
Parameter	As-Grown	Hg-Annealed	Se-Annealed	Hg, then Se Annealed	Unit
n_1	1.48	3.95	1.70	1.71	$x10^{16}$ cm^{-3}
μ_1	21,304	13,973	22,205	23,298	cm^2/Vs
n_2	4.40	4.21	1.23	0.85	$x10^{16}$ cm^{-3}
μ_2	4,285	4,279	6,233	6,429	cm^2/Vs
σ_1	50.51	88.42	60.47	63.82	$1/\Omega cm$
σ_2	30.20	28.86	12.28	8.75	$1/\Omega cm$
σ_o	13.66	7.17	5.87	4.20	$1/\Omega cm$
σ_1	53.52	71.05	76.91	83.13	%
σ_2	32.00	23.19	15.62	11.40	%
σ_o	14.47	5.76	7.47	5.47	%

78K Minority Carrier Lifetime

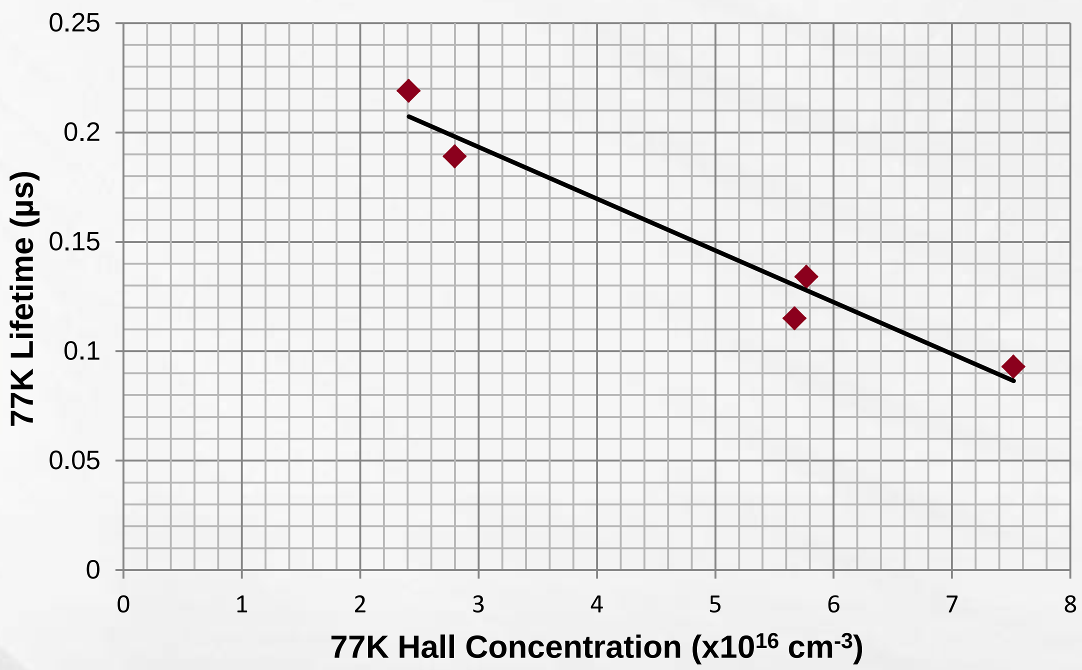








78K Lifetime vs. Doping



- Transients were fitted. For samples with more than one slope, the first slope was taken as the photo-conductance lifetime.
- As electron concentration decreased with annealing, lifetime increased.
- Longest 77K lifetime was observed for sample annealed under Hg then Se (220 ns)

Summary and Future Work

- Major source of HgCdSe background electron concentration is Group VII impurities (Br, Cl, F) introduced from Se source material
- Change in concentration with annealing suggests p-type Hg vacancies and n-type Se vacancies
- QMSA suggests an inhomogeneous distribution of electrons introduced in growth, reduced with Hg-then-Se anneal making mobility more discrete
- Lower electron concentration allows us to see PCD transients, which suggest trap present in as-grown material that is increased with Hg-annealing but removed with Se-annealing, could be Se vacancies
- Lowering background electron concentration and increasing lifetime will require higher purity Se and optimized anneal process

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77K Hall Mobility

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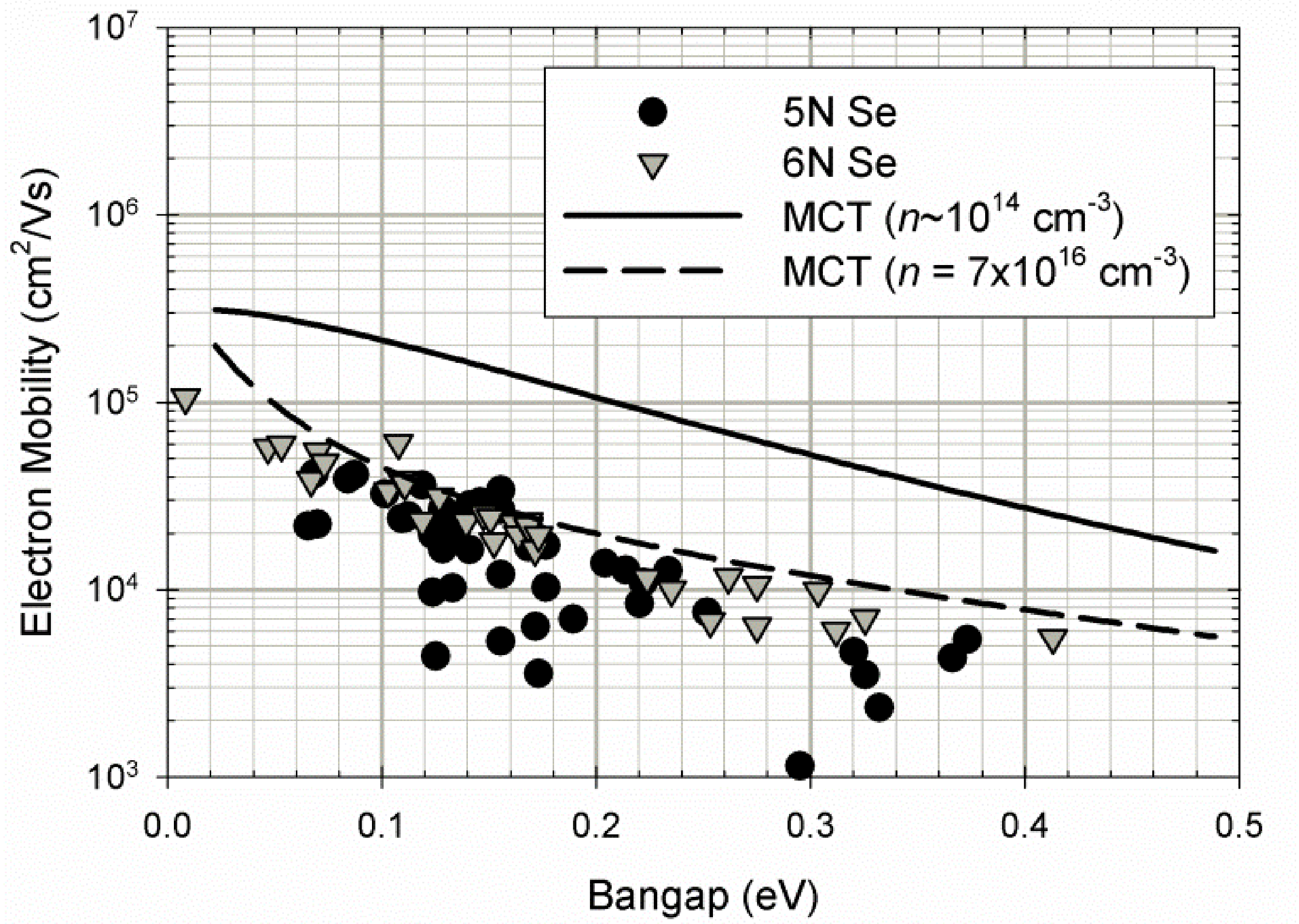
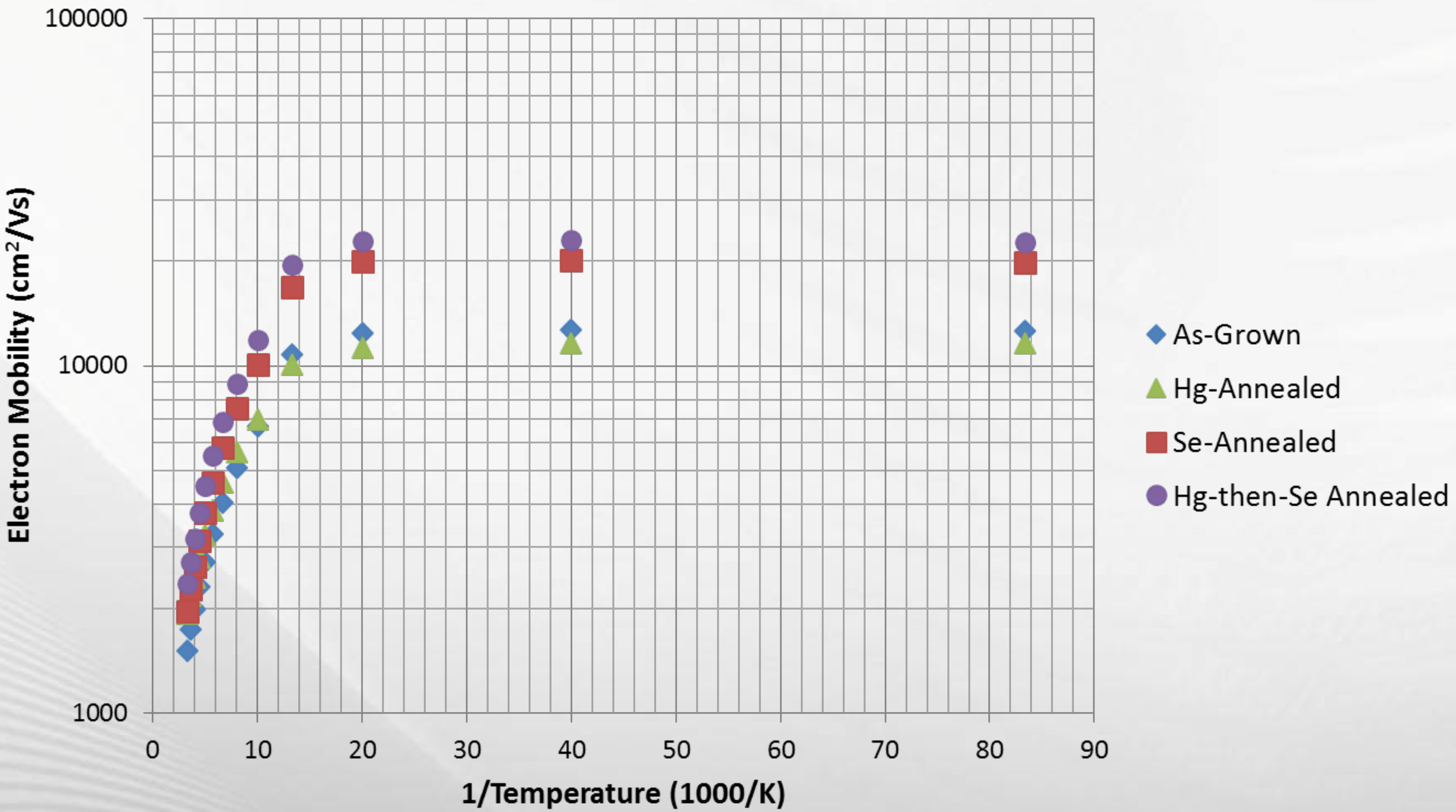


As-grown HgCdSe electron mobility comparable to HgCdTe of similar electron concentration.

K. Doyle, *Doctoral Dissertation, WVU Library (2013).*

Electron Mobility vs. Temperature



- Electron mobility raised/lowered with concentration after anneal

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Lifetime vs. Temperature

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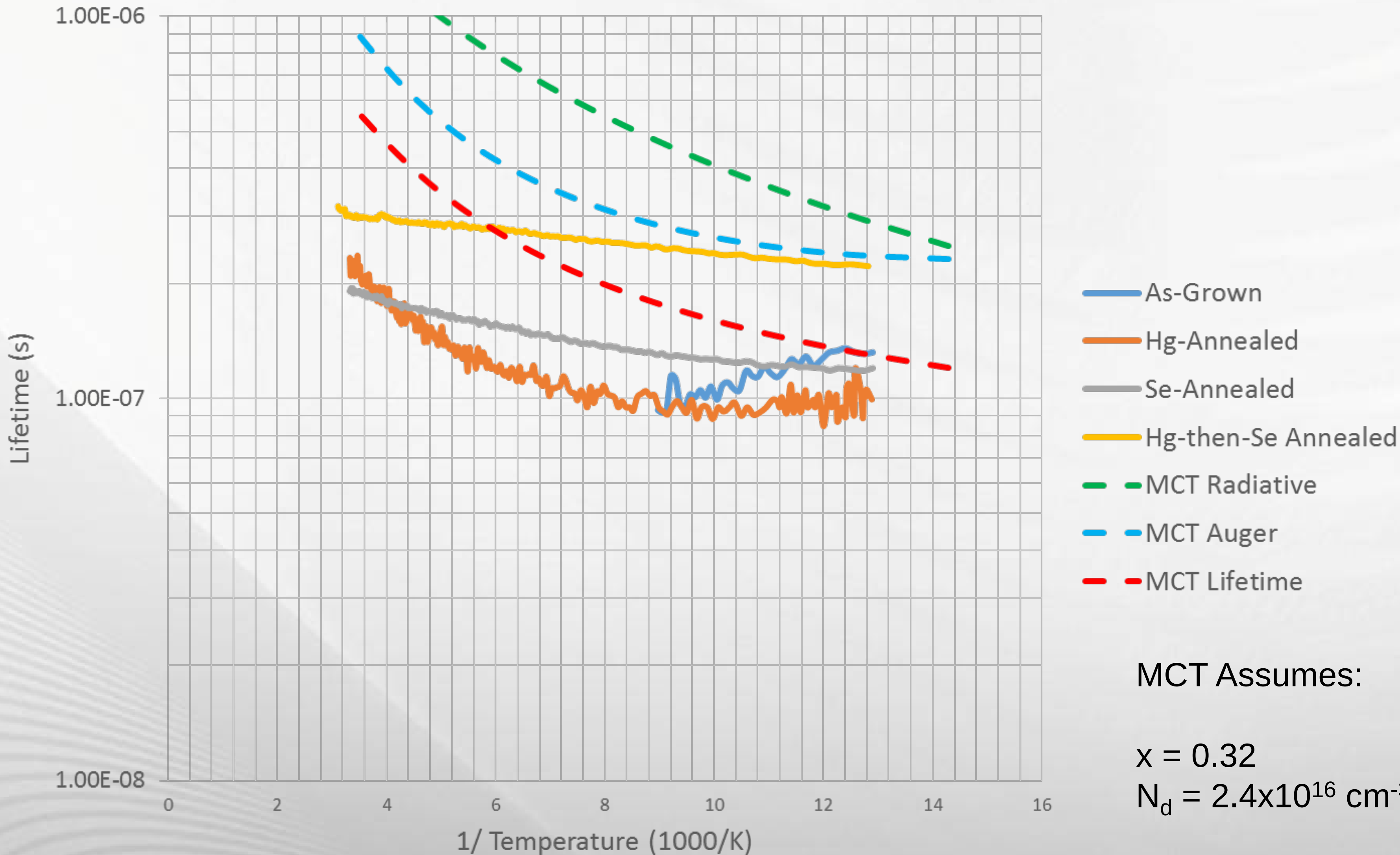

MCT Assumes:

$x = 0.32$

$N_d = 2.4x10^{16}\ cm^{-3}$

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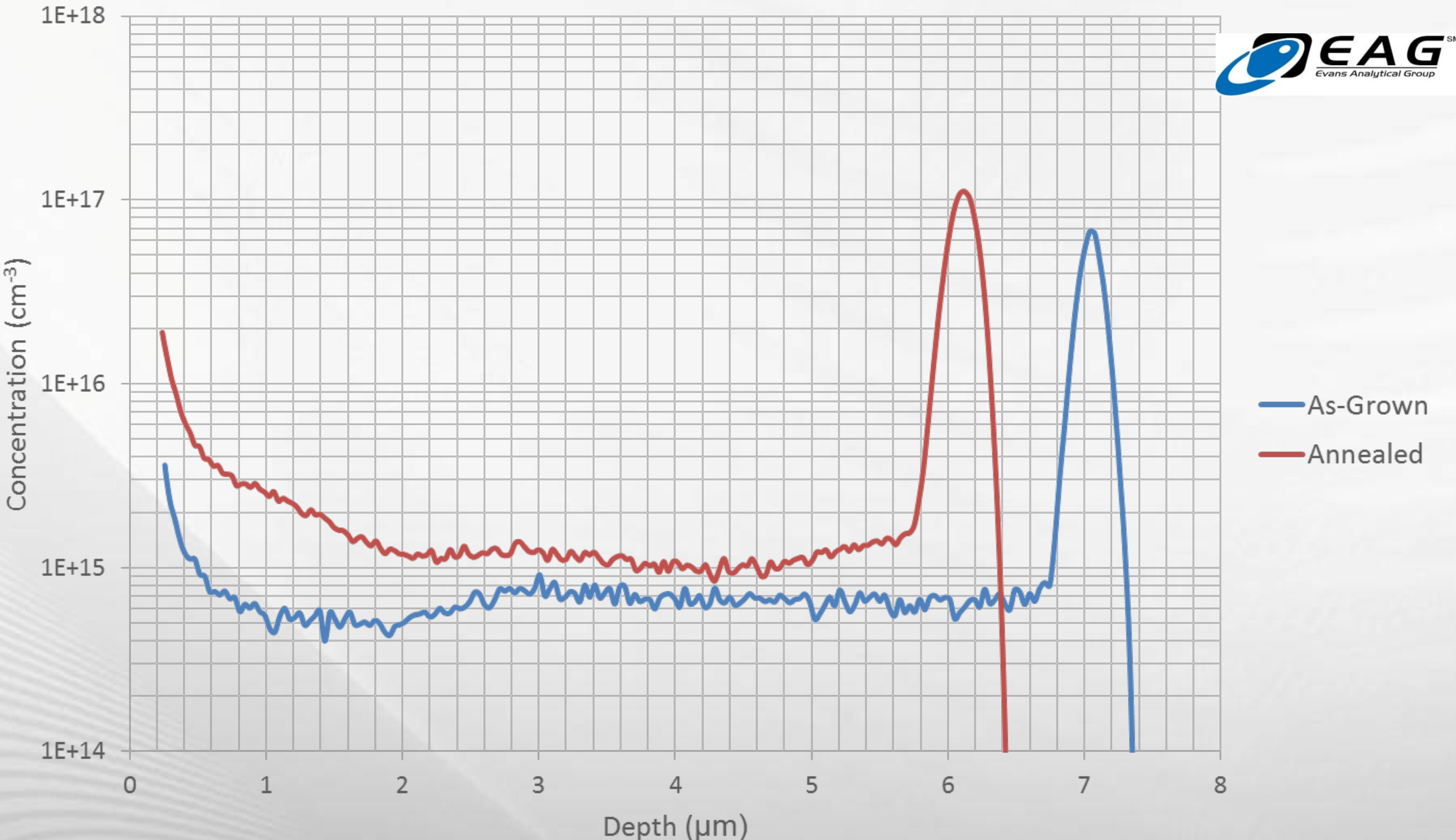
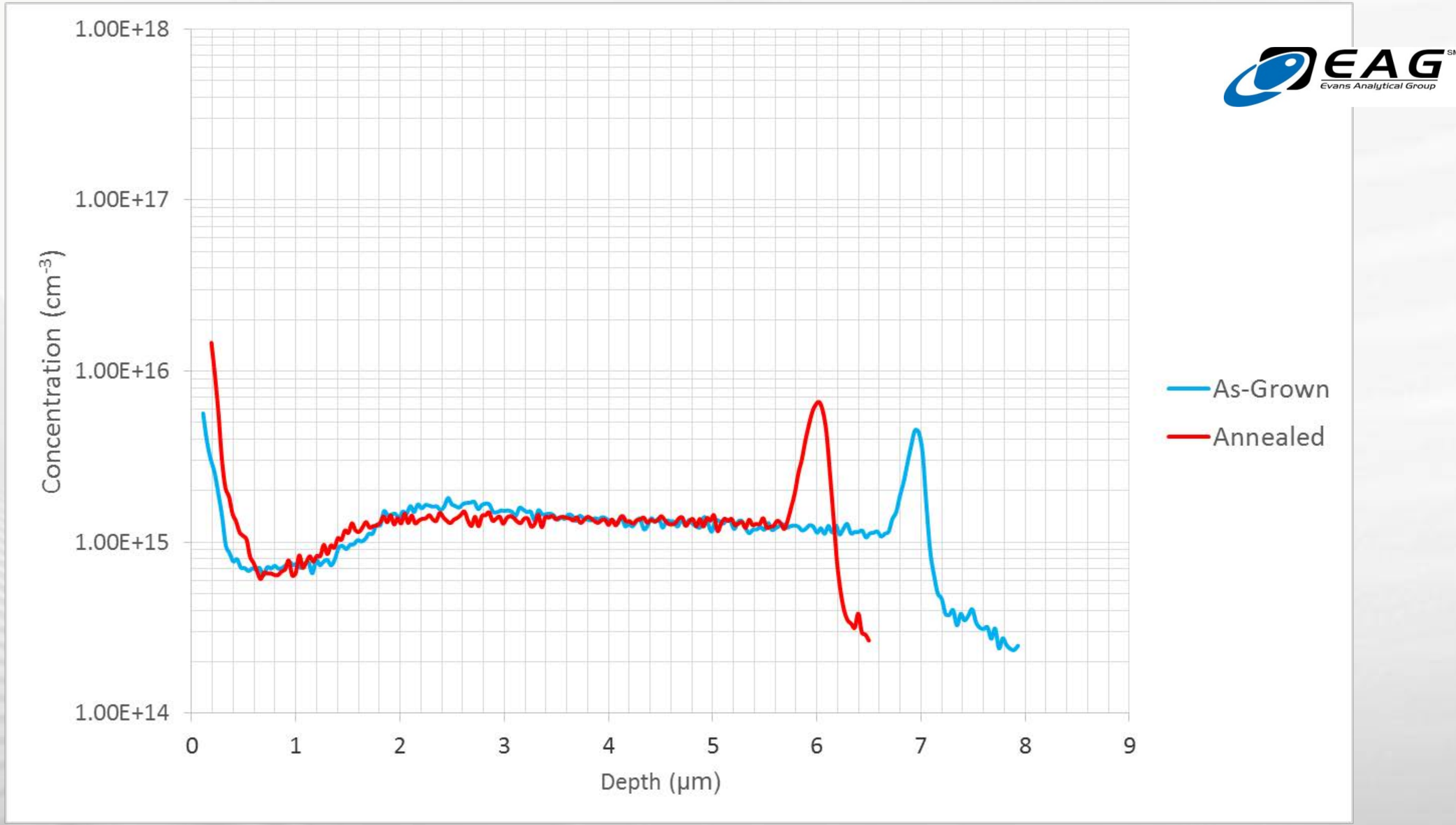
Br concentration (SIMS)

ARL



Cl concentration (SIMS)



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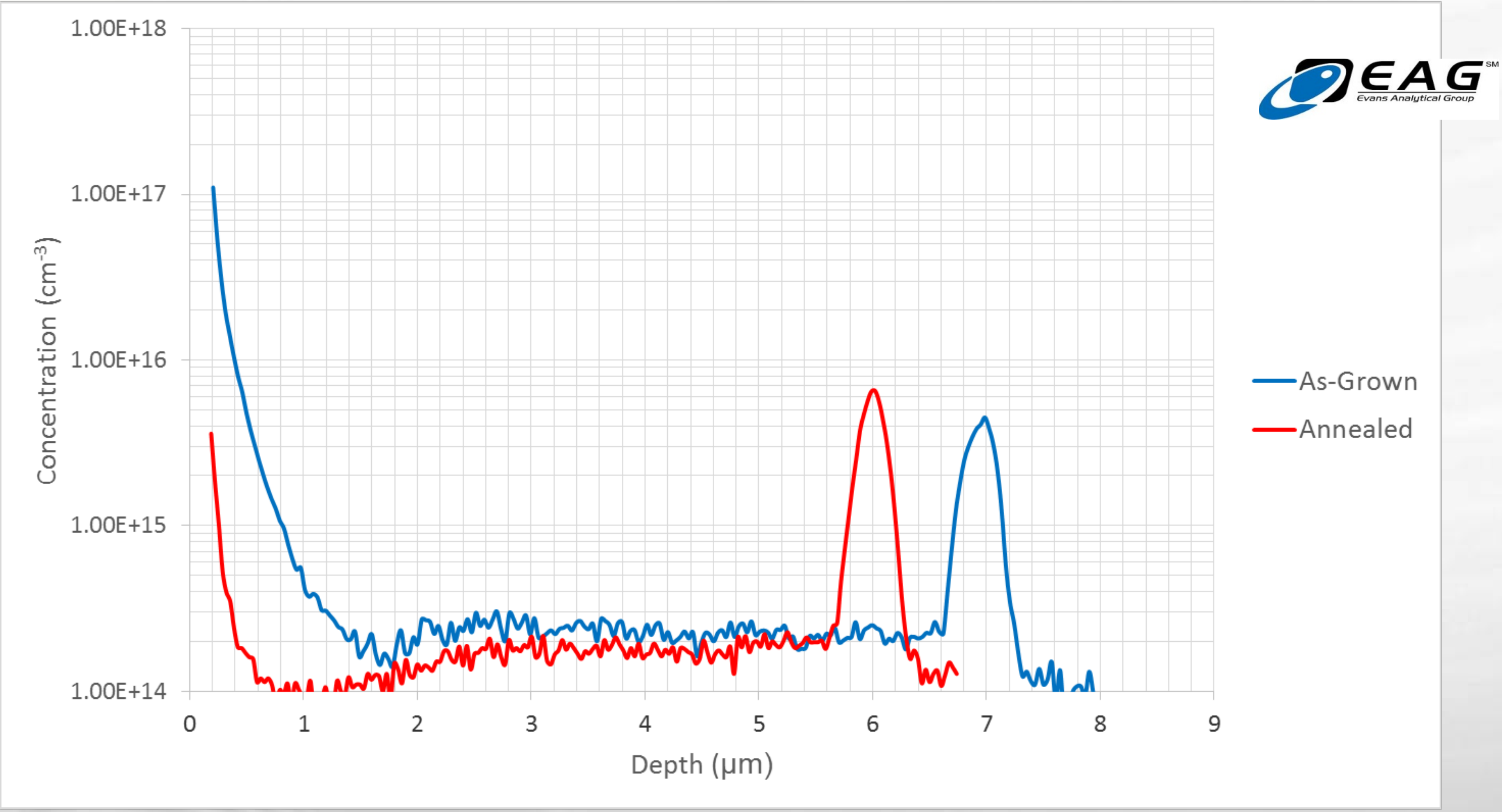
F concentration (SIMS)

ARL



77K Hg-Annealed Variable Field Hall

Stage	Element	Temp.	Duration
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$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1+(\mu_1 B)^2} + \frac{en_2\mu_2}{1+(\mu_2 B)^2} + \sigma_o$$

(μB) <<1

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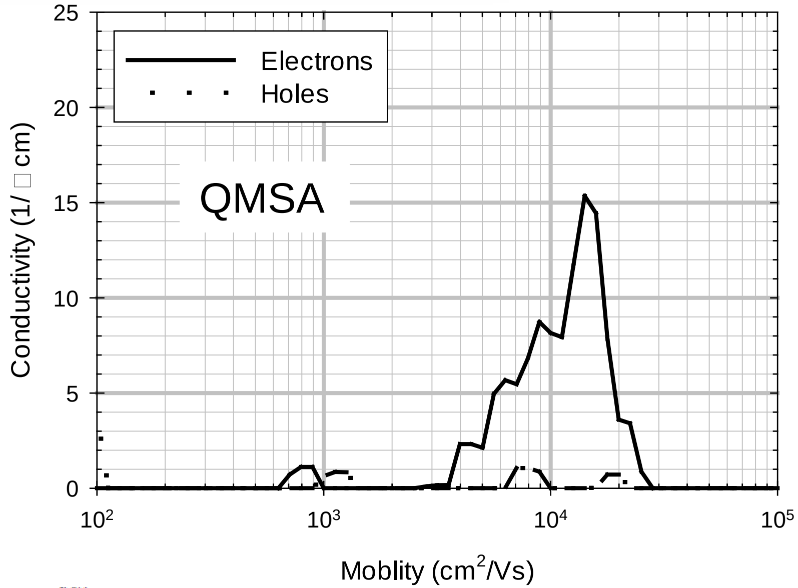
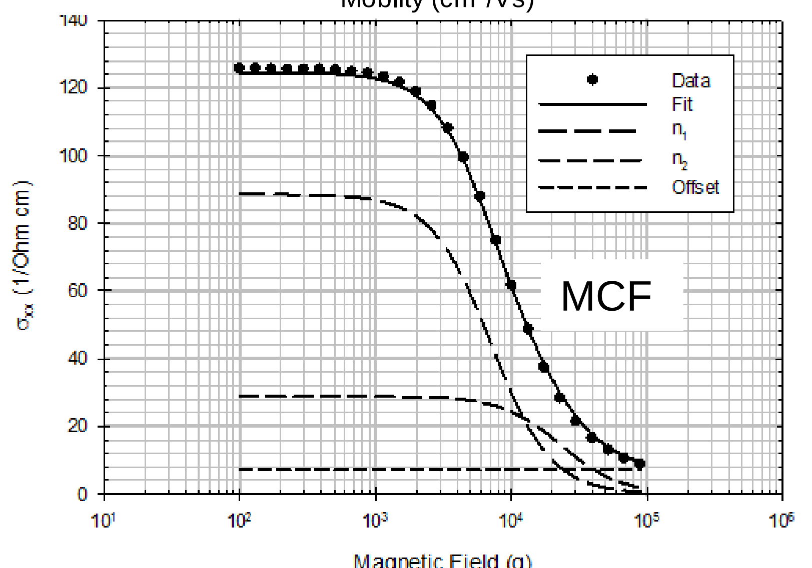
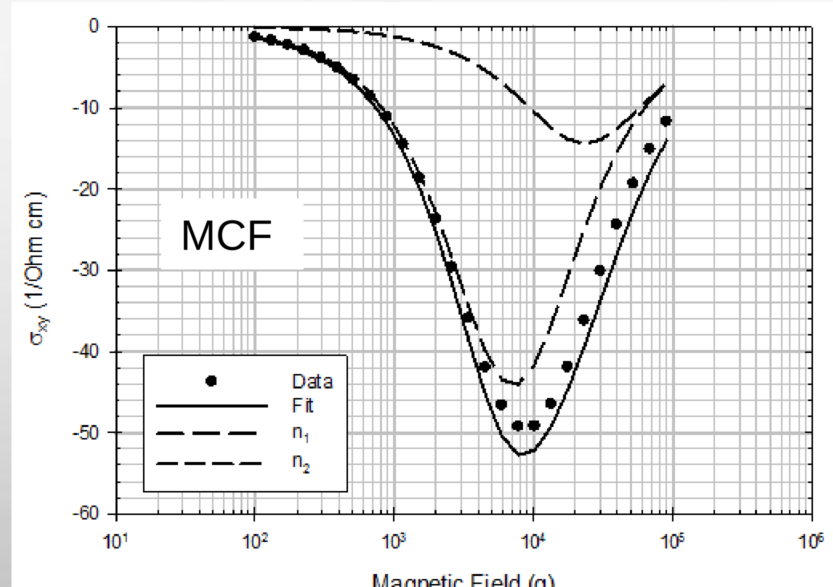


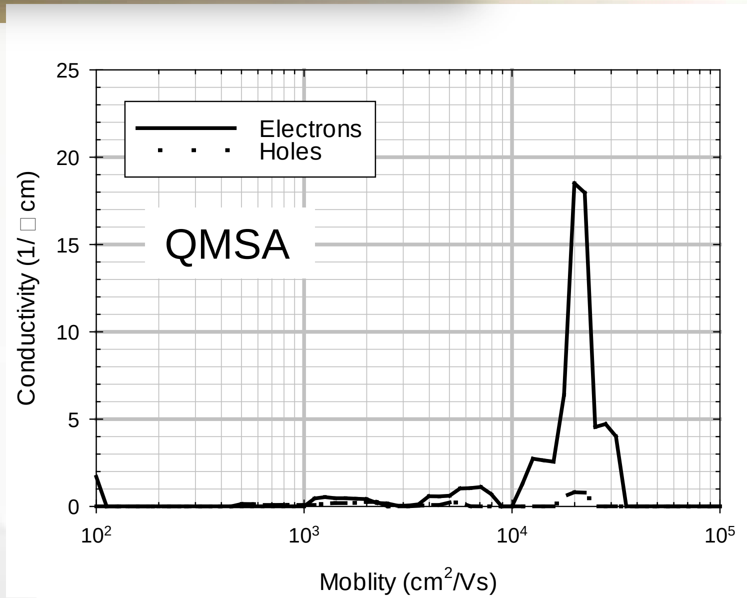




K. Doyle, *Doctoral Dissertation, WVU Library (2013).*

77K Hg-Annealed Variable Field Hall

Stage	Element	Temp.	Duration
1	Se	250 °C	24 hrs



$$\sigma_{xx}(B) = \frac{en_1\mu_1}{1+(\mu_1 B)^2} + \frac{en_2\mu_2}{1+(\mu_2 B)^2} + \sigma_o$$

(μB) <<1

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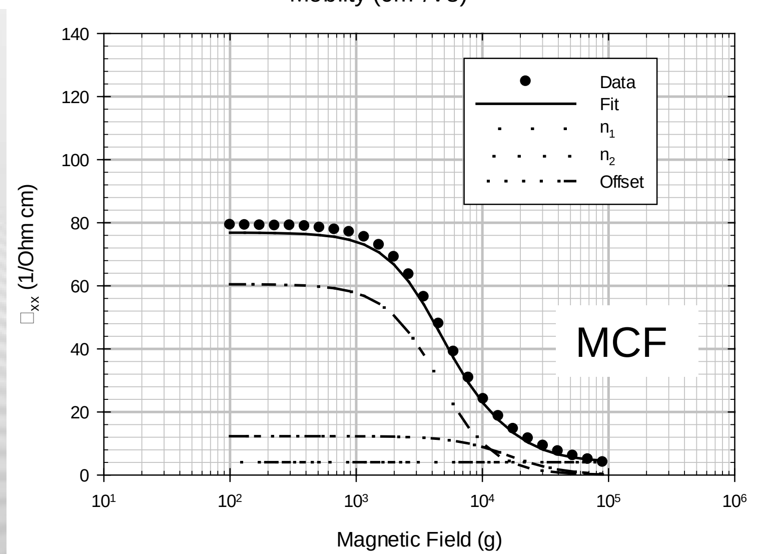

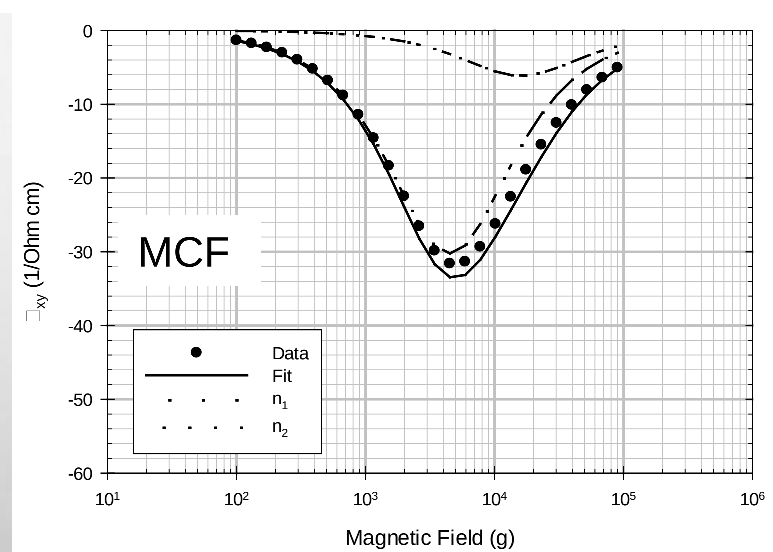

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